Contribution to the discussion on the origin of bright patches in loessic areas with Chernozems (Case study: selected part Trnavská pahorkatina Hill Land, Slovakia)

Smetanová, A.[1]

[1] Department of Physical Geography and Geoecology, Comenius University in Bratislava, Mlynská dolina, Bratislava 84 215, Slovak Republic. Tel.: 00421-2-60296259; Fax: 00421-2-65429064; E-mail: smetanovaa@fns.uniba.sk

1. Abstract

Bright patches on the surface of loessic hill lands with Chernozems are widely spread in the Danube Lowland. So far the water and partly wind erosion were considered to be the main processes responsible for their creation while the role of the tillage erosion was thought to be of low importance. The objective of this study was to contribute to the discussion on the origin of these patches. The relationship between the spatial distribution of bright patches and relief was assessed. DEM and derived DTMs were created using the tools of GIS. Bright patches were identified on the basis of aerial photographs and orthophotomaps and the database containing characteristics of all patches was created. Total of 777 bright patches were described. The relation to relief parameters, occurence of archeological sites, old and current land use patterns and geomorphic processes were researched. Our results suggests that considerable part of patches, especially those of regular, long narrow shape and linked with terrain edges were formed mostly by tillage erosion. The origin of small, irregular and chaotically dispersed patches seems to be more complex. We presume that they might have been formed by combination of several processes typical for morphogenesis of loessic hill land.

Key words: bright patches, loessic hill land, relief morphogenesis, DEM, raster statistics, water erosion, tillage erosion, Slovakia

2. Introduction

The bright patches represent areas where humus horizon of soils is not present and the maternity rock – loess is visible on the surface. They are typical feature of arable land in loessic areas. The problematic of their occurrence, distribution, soil properties (e.g. Ilavská and Jambor 2005, Sobocká, 2002) is frequently studied. Also processes contributing to genesis of areas without humus horizon (e.g. Bac 1928, Van Muysen et al. 1999, Van Oost et al. 2000, Sviček 2003) or their long term effect on morphogenesis (Van Oost et al. 2005, Peeters 2006, Janicki et al. 2002) are in the centre of interest for many years.

In the territory of Slovakia the genesis of bright patches was first studied by Linkeš et al. (1992) who designed relict water erosion to be the main contributing process. Stankoviansky (1993) stressed the role of eolian processes on polygenetic creation of bright patches. Possible relationship between their occurrence in flat areas and archaeological sites was suggested (Kohan 1993). Fulajtár (1994) described water erosion as the main bright patches - forming process, which influenced mainly slopes longer than 100m and steeper than 2°. Soil erosion model such as USLE (Wischmeier and Smith 1978) and other methods are used to estimate the extent and intensity of water erosion. Intensity of 15 t. ha $^{-1}$ was assessed in Voderady by measuring the content of ^{137}Cs (Linkeš et al. 1992). The scientific papers concerning the evaluation of other processes contributing to creation of bright patches or relief morphogenesis in loessic areas of Slovakia are less frequent. The importance of tillage erosion processes on arable land was stressed in several studies (Lobotka 1958, Zachar 1970, Stankoviansky 2001). However, they were not studied in details. The aim of the study is to contribute to discussion on bright patches genesis using detailed relief analyses and tools of GIS.

3. Methods

Studied area of 31.3 km^2 is situated in SW of Trnavská pahorkatina Hill Land, which belongs to Danube Lowland. Chernozems strongly affected by erosion prevail in this loessic region, where humus horizon is removed on approximately 12 % of the area. Due to neotectonic fault activity two local depressions dissecting softly modelled relief of the study site (with average slope 0.7°) occur and the whole area decline slightly in SE direction. The steepest parts with maximum slope of 8.6° are situated on depression's slopes with significant height difference 9–14m (Stankoviansky 1993). Almost whole area (90%) is used as arable land, where massive use of mechanical tillage tools has been predominant since 1950s.

The relationship among relief characteristics and bright patches distribution was evaluated using DEM, aerial images and orthophotomaps analyses in GIS. DEM and related DTM's were created on the basis of vectorized topographic maps and GPS terrain measurements. Using visual analysis of ortorectified aerial images and digital orthophotomaps in GIS 848 bright patches with total area of 4.18 km^2 were identified. Patches partly covered in vegetation or crop residues were excluded from the study. Data for remaining 777 patches (3.72 km^2) were analyzed and forty-five relief parameters concerning area, slope, orientation, elementary forms, contributing area and position on the slope were computed. The basic statistic values (average, range etc.), total or percentual area as well as combination of elementary form, orientation and curvature change in each patch were summarized in the database. Relationship between occurrence of bright patches and relief was analysed afterwards.

The bright patches's genesis evaluation was performed with the regard to occurrence of archaeological sites and influence of water and tillage erosion. WATEM model (Van Oost et al. 2000) was used to assess the contribution of water erosion on the bright patches's genesis in two smaller areas. Respective values of R and K parameters were previously published (Styk and Pálka 2005, Ilavská 2005, Ilavská and Jambor 2005). C parameter was counted from crop rotation data in years 2004 – 2006 using the methodology described by Šúri et al. (2002). Due to inappropriate data for tillage erosion modelling (in WATEM, Van Oost et al. 2000) we distinguish the areas formed by this process using neighbourhood raster statistic. Based on the precondition that (topography - based) tillage erosion rates increase with the change in slope gradient (Van Oost et al. 2005) areas where the change in slope (slope range) is higher than average were identified. Obtained data were further evaluated and areas with the value of slope position lower than the average were identified as created mainly with tillage erosion. The bright patches distribution was compared with current and old (pre-collectivization) land use pattern using visual analysis.

4. Results

The bright patches covering almost 12% of the study site area vary in size and shape. Small, in shape variable patches (elliptic, beans – like, curved etc.) often elongated in the slope direction are predominant in the western part of the studied area. On the other hand, regular, long and narrow shaped patches lie in the highest parts of the terrains such as ridges and tops. The same situation was observed on the terrain edges of the slopes in eastern part of the study site. Bright patches are less frequent in terrain depressions, where irregular polycurved shapes occur more often. Approximately half of the patches are smaller than 0.25 ha and only 10% of them are larger than 1ha. They occur in all slope categories except of the steepest part with slope higher than 6°. The majority of bright patches occur on the slopes with inclination ≥ 0.5. However, the total area of bright patches situated on slopes with inclination 1 – 3° was 1.66-fold higher than was supposed presuming that direct correlation exists between the characteristics of relief and those of the bright patches. Similar situation was observed for patches on slopes with inclination of 3 – 6 °, which occur 1.32-fold frequently. The orientation of the patches is mainly southward, 43% of the patches have S, SW or SE orientation. Assessing occurrence of elementary forms within bright patches we found 198 combinations. More than half of the patches contain transitions of both curvatures and 25 % are linked only with the change in profile curvature. Convex – convex forms are most frequent within patches and they occur within them more often than in relief. On the other hand 49% of patches contain concave – concave form. Studied bright areas lie mostly in upper parts of slopes (only 17% are close to local thalweg) and have relative small average contributing area (50% smaller than $100m^2$).

Two direct relationships between occurrence of archaeological sites and bright patches were identified. However, we suppose other relationships which were not proven due to the lack of data concerning the exact location of archaeological sites. There is a strong evidence of long – term soil exploitation since paleolit period described by Pavúk and Mináč (1977) who discovered abandoned Neolithic and early – middle age villages on significant part of our studied area. Further studies are required to evaluate and analyse the previous human influence on relief changes in this area with high frequency of bright patches.

Modelling of water erosion proved its lower influence mainly in upper parts of slopes, where erosion rates with maximum 0.25 $t.ha^{-1}$ were assessed. It increases up to 8 $t.ha^{-1}$ in areas closer to local thalweg and accumulation occurs in concave parts nearby. Comparison of the results obtained by modelled water erosion and distribution of the patches revealed their presence mainly in areas with very low intensity of this type of erosion. The potential for topography-based tillage erosion influence was evaluated by the means of raster statistics and compared with patches distribution. Total of 192 patches partly or completely coincident with variable (in extent and position within patches) slope gradient were identified. The dependence is most apparent among regular, long and narrow – shaped patches linked with terrain edges, hilltops and ridges or upper parts of slopes (Figure 1). Their area usually bound with convex forms of profile curvature with absence (or insignificant representation) of concave – concave forms. The water erosion intensity is very low in these areas. Therefore we suggest that these bright patches were created by tillage erosion. This correspond with Van Muysen et al. (1999), who proposed that erosion on the edges in the upper parts of slopes was not exclusively caused by water contribution, as these areas have lower slope and small contributing area. Bac (1928) obtained similar results and attributed this erosion to tillage tools usage.

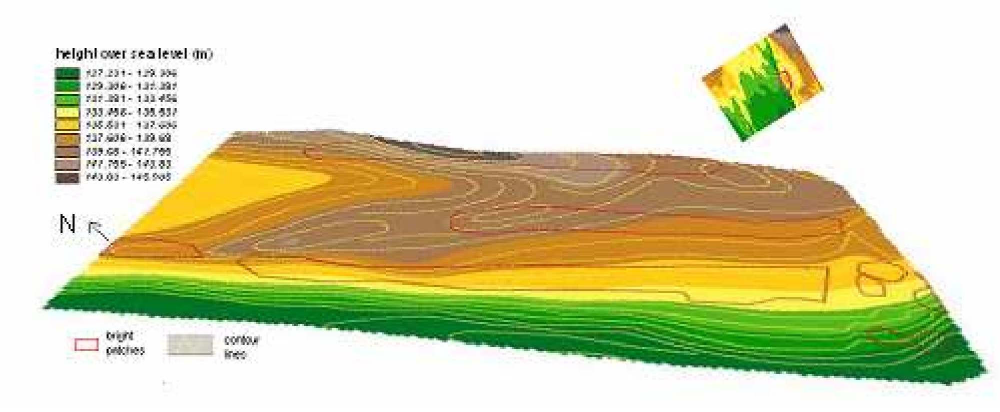

Figure 1 Bright patches on terrain edges and upper parts of slopes formed by tillage erosion

In the western part of the studied area occurrence of evaluated slope gradient and patches is often connected with the transition between convex and concave elementary forms. Bright areas are more variable in all characteristics, larger extents of concave – concave forms within patches occur and patches are distributed within the slope (Figure 2).

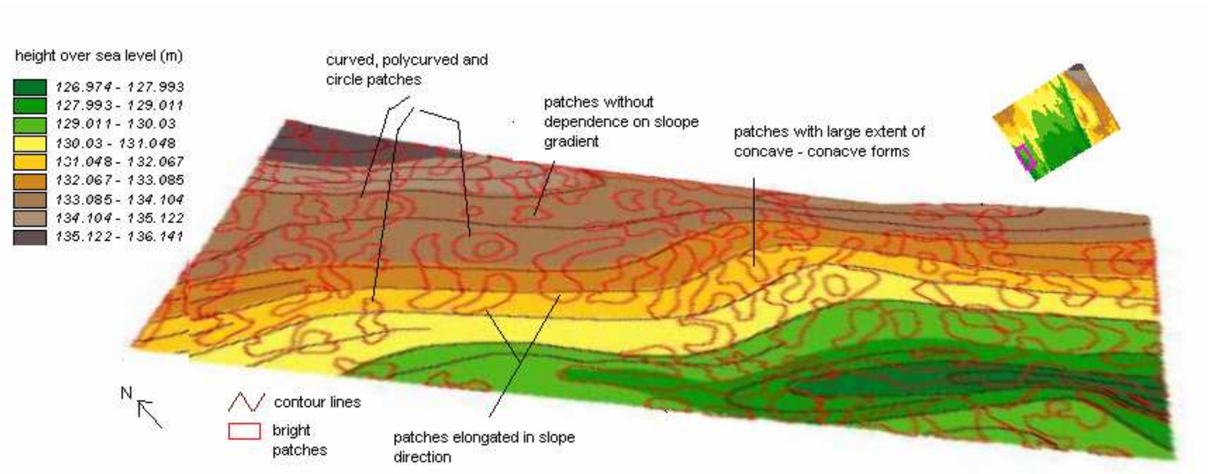

Figure 2 Bright patches with complex origin

We assume that their origin is more complex, with contribution and antagonistic effect of water and tillage erosion, accumulation changing in space and time according to land use changes in the past. Some pieces of evidence were obtained by comparing with pre – collectivization land use pattern. Spreading of patches in post – collectivisation period is apparent. However, many of them already existed in the middle of 20^{th} century, including those considered to be created by tillage erosion. Similar eroded areas were identified by Bac (1928) in the beginning of 20^{th} century and as was noticed above he assumed them to be created by tillage erosion. On the other hand Van Oost et al. (2005) proposed that tillage erosion had insignificant effect on morphogenesis before 1950. Narrow patches elongated in slope visible in pre – collectivization images seem to be connected with long narrow fields tilled and elongated in the same down slope direction. Further research with more detailed DEM's and aerial image processing as well as usage of other (probably interdisciplinary) methods are needed to evaluate the origin of bright patches and the relief morphogenesis in arable land.

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